bananalearn

GRADE 10 / SCIENCE

Chapter 10

The Human Eye and the Colourful World



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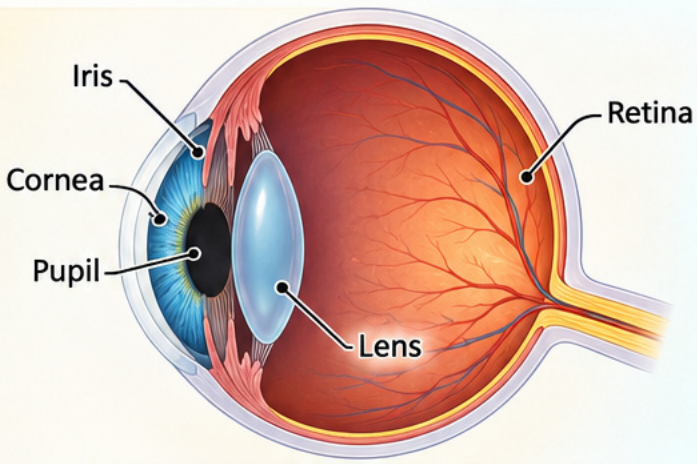
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Accommodation in the eye

The human eye can see objects near and far clearly by changing the focal length of its lens. This ability is called **accommodation.**



Main parts and functions

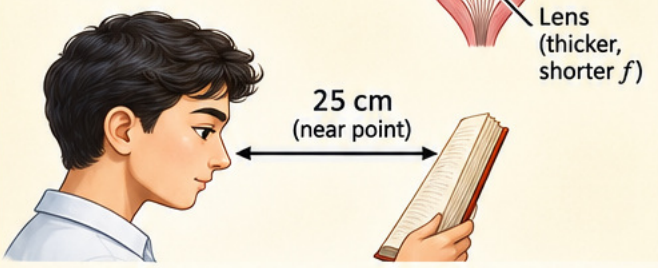
- **Cornea:** transparent, curved front layer; bends incoming light.
- **Iris:** coloured, muscular part; controls the size of the pupil.
- **Pupil:** an opening that lets light in.
- **Lens:** transparent, flexible; changes its curvature (focal length) for clear focus.
- **Retina:** light-sensitive screen; forms a real, inverted image.

Accommodation: in brief

The ciliary muscles change the curvature of the lens to adjust its focal length (f) so that the image of an object, whether near or far, is formed on the retina.

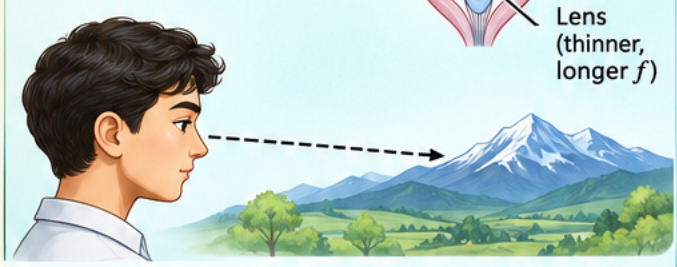
Focusing a near object

- Ciliary muscles contract.
- Lens becomes thicker (more convex).
- Focal length becomes shorter.



Focusing a far object

- Ciliary muscles relax.
- Lens becomes thinner (less convex).
- Focal length becomes longer.



Near point: The least distance of clear vision for a normal young adult is about 25 cm.

Worked Example (Reasoning)

What changes for near vision?

A near object sends more divergent rays to the eye than a distant object. To keep the image on the retina, the lens becomes more convex and its focal length decreases.

A near point of 25 cm alone does not determine the power of the eye lens.

Self-Check

Q. Which change occurs in the eye when a near object is viewed? What is the near point of a normal young adult?

Answer:

- Ciliary muscles contract, the lens becomes thicker (more convex) and its focal length decreases (shorter f).
- The near point is about 25 cm.

Myopia and hypermetropia

Compare where rays from the object would meet with where the retina actually is. A correcting lens changes the incoming beam.



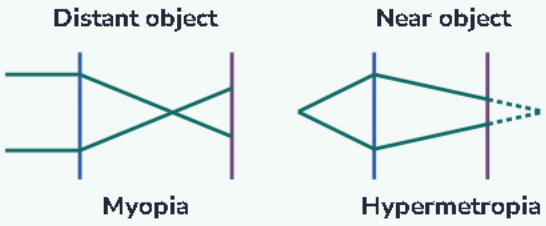
Near object



Concave correction



Convex correction



Blue = eye lens Purple = retina

Myopia → diverging lens (−) • Hypermetropia → converging lens (+)

Uncorrected eyes: compare where each set of rays meets.

Myopia

For a distant object, nearly parallel rays meet in front of the retina in the relaxed myopic eye. The far point is at a finite distance.

Myopia correction

A concave lens spreads incoming light so it appears to come from the eye's far point. The eye can then focus it on the retina.

Hypermetropia

For a nearby object, the eye may lack enough converging power or be too short. At a near distance beyond the eye's focusing ability, the rays would meet behind the retina.

Hypermetropia correction

A convex lens makes rays from the book less divergent. With suitable accommodation, the eye forms the book's image on the retina.

WORKED EXAMPLE

A myopic eye has a far point 2 m away. Estimate the lens power for distant vision.

For an object at infinity the lens forms a virtual image at the far point. $f \approx -2$ m, so $P \approx -0.50$ D; take the lens to be close to the eye.

SELF-CHECK

Is the image of a nearby book automatically at the eye's principal focus?

No. The principal focus is defined for incident rays parallel to the axis. A nearby book sends diverging rays.

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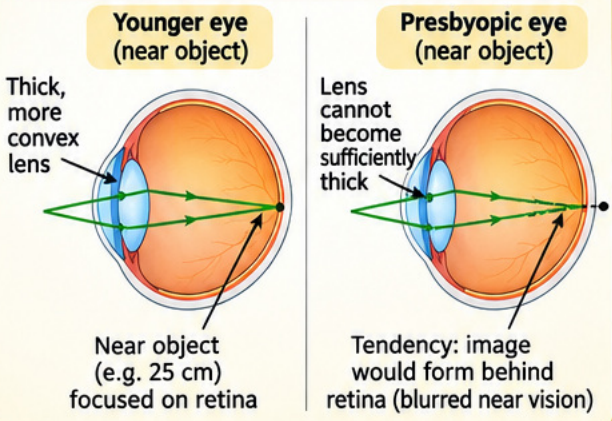
Presbyopia and correction

What is presbyopia?

Why near focus becomes harder

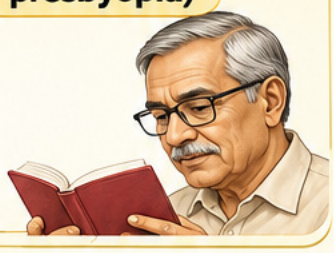
With age the lens becomes less flexible and accommodation declines. The near point recedes. A suitable converging reading lens reduces the focusing effort needed for close work.

Accommodation: younger vs. older eye



Reading lens (for presbyopia)

A convex (converging) lens of suitable power is used for near work (e.g. reading), so that a near object forms its image on the retina.



Not the same as eyeball-length defects

Separate the causes

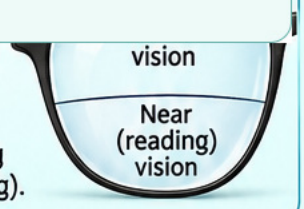
Presbyopia: reduced accommodation with age.

Myopia: the eye is too long or converges light too strongly for distant vision.

Hypermetropia: the eye is too short or has insufficient converging power for near vision. Its near point can be farther away than normal.

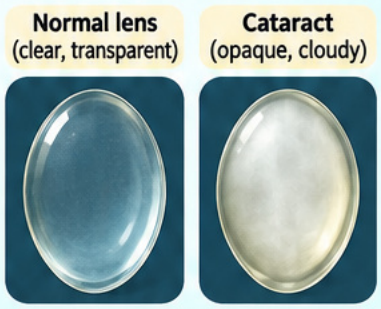
a single lens with two parts is used:

- **Upper part** – for distant vision (e.g. when walking or driving)
- **Lower part** – a convex reading lens for near vision (e.g. reading).



Cataract – a different problem

Cataract is the **opacity** (clouding) of the eye lens due to ageing, injury or other causes. It reduces the amount of light reaching the retina and causes a dim, hazy vision (with or without glare), not a problem of accommodation.



Worked example (reasoning)

Problem: The near point of a person with presbyopia is 50 cm. Find the power of the reading lens needed so that he can read comfortably at 25 cm.

Solution: The lens should form a virtual image of an object at $u = -25$ cm at the person's near point $v = -50$ cm.

Using $\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$,

$$\frac{1}{f} = \frac{1}{-50} - \frac{1}{-25} = \frac{-1}{50} + \frac{1}{25} = \frac{1}{50}$$

$$\Rightarrow f = +50 \text{ cm} = 0.50 \text{ m}$$

$$\text{Power, } P = \frac{1}{f} = \frac{1}{0.50} = +2.0 \text{ D.}$$

Answer: A +2.0 D (convex) reading lens is required.

Self-check (with answer)

Q. A 60-year-old person has a near point of 1.0 m. What is the power of the reading lens required to read a book at 25 cm?

Solution: Here, $u = -25$ cm and $v = -100$ cm.

$$\frac{1}{f} = \frac{1}{-100} - \frac{1}{-25} = \frac{-1}{100} + \frac{1}{25} = \frac{3}{100}$$

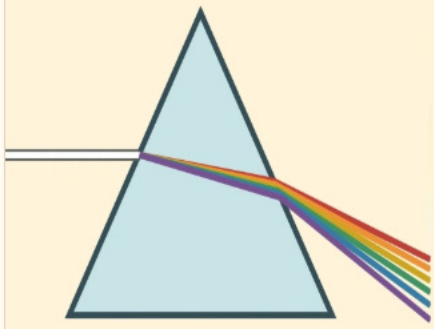
$$\Rightarrow f = \frac{100}{3} \text{ cm} = 0.333 \text{ m}$$

$$P = \frac{1}{f} = \frac{1}{0.333} \approx +3.0 \text{ D.}$$

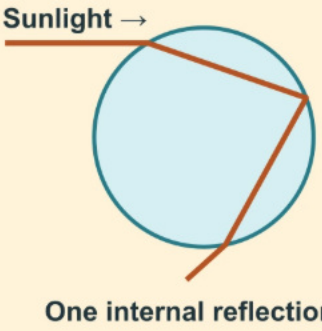
Answer: +3.0 D (convex) reading lens.

Prisms and dispersion

A prism spreads white light because its refractive index varies with wavelength. A raindrop adds a reflection inside the drop.



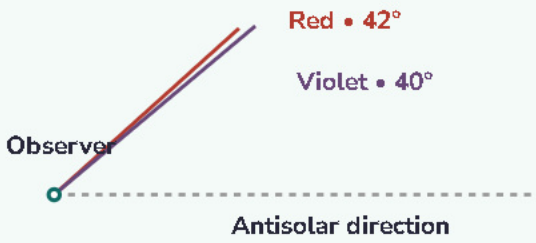
Dispersion in a prism



Refraction and reflection



Primary rainbow



Primary rainbow • red outer edge ≈ 42° • violet inner edge ≈ 40°

Sight lines measured from the point opposite the Sun

At a glass prism

Light refracts at entry and exit. In ordinary glass, violet has a higher refractive index than red and deviates more towards the base.

Spectrum

Visible wavelengths form a continuous band. The familiar colour names divide that band into convenient groups.

Inside a raindrop

Sunlight refracts and disperses at entry, reflects once inside the drop and refracts again on leaving. Different drops send different colours to the observer.

Angle reference

Measure the radius of the bow from the antisolar direction, the point opposite the Sun. Red has the larger radius and appears outside violet.

WORKED EXAMPLE

Where should you look for a rainbow when the Sun is low behind you?

Look towards raindrops opposite the Sun. For a given observer, red comes from drops about 42° from the antisolar direction and violet from about 40°.

SELF-CHECK

What happens if a second matching prism is placed suitably inverted after the first?

The separated colours can recombine into white light.

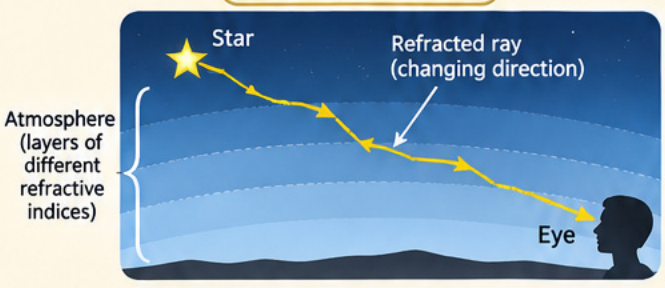
Atmospheric optics

The Earth's atmosphere, though transparent, changes the path and scattering of sunlight. This causes twinkling of stars, apparent early sunrise, the blue colour of the sky and the reddish colour of the Sun at sunrise and sunset.

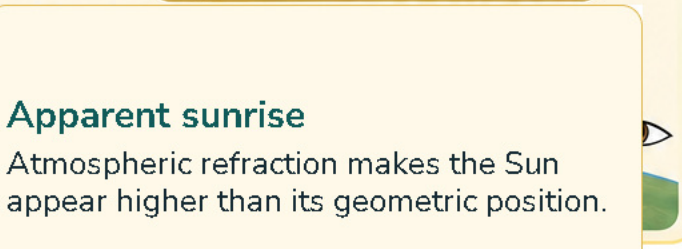
Refraction in the atmosphere

- **Twinkling of stars:** Starlight passes through continually changing layers of air (different refractive indices due to temperature and density changes). Its direction keeps varying, so the intensity at the eye fluctuates — the star appears to twinkle.
- **Apparent sunrise:** Due to atmospheric refraction, rays from the Sun bend towards the normal (n_{air} increases nearer the ground), so we see the Sun about 2 min earlier than the actual geometric sunrise (and about 2 min later at sunset).

Twinkling of a star



Apparent sunrise due to refraction



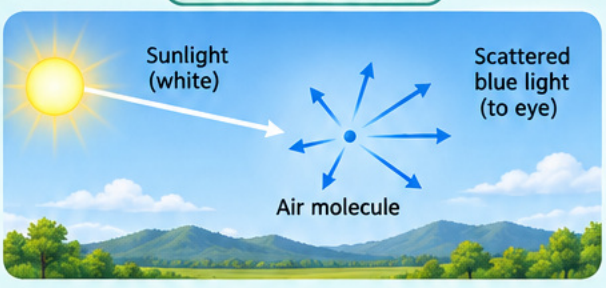
Apparent sunrise

Atmospheric refraction makes the Sun appear higher than its geometric position.

Scattering of sunlight

- **Blue sky:** Air molecules (size ≪ wavelength of light) scatter shorter-wavelength blue–violet light much more (Rayleigh scattering, intensity $\propto 1/\lambda^4$). The scattered blue light from all directions makes the sky appear blue.
- **Reddish sunset/sunrise:** When the Sun is near the horizon, its light travels a much longer path in air. Most of the shorter wavelengths are scattered away; the less-scattered longer wavelengths (red–orange) reach our eye, so the Sun appears reddish.

Why the sky is blue



Why the Sun is reddish at sunset



Why do planets twinkle less?

Planets are much nearer and appear as extended disks (not point sources). Light from different parts of the disk undergoes slightly different deviations, which average out, so their brightness varies very little.

Why is the sky dark in space?

There is no atmosphere to scatter sunlight, so the sky appears black even in daytime.



Worked example (Reasoning)

On a clear day, the Sun is seen at 6:00 a.m. If the usual advance due to atmospheric refraction is about 2 min, when does the actual sunrise (geometric) take place?

Solution: The Sun is seen 2 min earlier than its actual position.

∴ Actual sunrise time = 6:00 a.m. + 2 min

= **6:02 a.m.**

Self-check (Answered)

Q. Why does the Sun appear reddish at sunset, while the sky looks blue during the day?

A. During the day, shorter-wavelength (blue) light is scattered much more by air molecules, making the sky blue. At sunset, sunlight travels a longer path; most blue light is scattered away and the less-scattered longer wavelengths (red–orange) reach the eye, so the Sun looks reddish.

ONE LAST CHALLENGE

Which colour takes the outside lane?

Stand with the Sun behind you and look at a primary rainbow. Which colour forms its outer edge?



THE REVEAL

Red takes the wider angle.

Measured from the direction opposite the Sun, red appears at about 42 degrees and violet at about 40 degrees.

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